The Future of Nuclear Energy Policy: A California Perspective

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Thank you, Commissioners, for this opportunity to speak at this workshop session on the future of nuclear energy policy. I am Per Peterson, a professor of Nuclear Engineering at U.C. Berkeley, a member of the Diablo Canyon Independent Safety Committee, and a co-chair of the Generation IV International Forum Experts Group on Proliferation Resistance and Physical Protection.

[SLIDE 2]

You have asked me to address several questions, which I will do briefly during this presentation.

Let us start with the recommendations of the National Commission on Energy Policy, which has identified four key goal areas for new nuclear power: cost, accidents and terrorist attacks, radioactive wastes, and proliferation risks.

During the coming decade will learn answer to the question of costs, through direct experience. With the recent passage of the Energy Bill, it is now assured that new nuclear power plants will be built in the United States. This bill gives 6,000 megawatts of new nuclear construction the same favorable loan terms and production tax credits as have traditionally been given to renewable energy sources.

[SLIDE 3]

To predict what future nuclear energy costs could be in the United States, we can start by going back to 1995. At that time, when deregulation made it possible for nuclear plants to be sold, we had seen a steady string of plant decommissioning announcements for poorly managed plants, those which ran at capacity factors too small to be economically viable. The popular view was that plant sales would accelerate this decommissioning trend.

Conversely, experts already knew that improved plant management practices could result in large increases in capacity factors—Diablo Canyon in California providing one of the earliest examples. Now, in 2005, plants which were sold are performing better than the fleet-wide average and the fleet-wide capacity factor exceeds 90%. Current nuclear reactors now have undeniably low electricity production costs, averaging below 1.7 cents per kilowatt-hour.

Today the popular view is that new nuclear power construction will be too expensive. However, experts see a different view. First, they see that short construction times—52 months—are now routinely achieved in Japan, for reactors of very similar design to those we will build here. Second, they see very large reductions in steel, concrete, and equipment that have been achieved with the most recent passively-safe nuclear power plant designs.

[SLIDE 4]

At U.C. Berkeley, we have recently completed a study to examine the material inputs required to build new nuclear power plants. Materials inputs, which for energy infrastructure are dominantly steel and concrete, provide a simple measure for capital costs. For safety-grade nuclear systems, engineers commonly apply a cost multiplier of 1.6 on material costs.

To review, nuclear power plants built in the 1970's used 40 metric tons of steel, and 190 cubic meters of concrete, for each megawatt of average capacity. For comparison, modern wind energy systems, with good wind conditions, take 460 metric tons of steel and 870 cubic meters of concrete per megawatt.

Modern central-station coal plants take 98 metric tons of steel 160 and cubic meters of concrete—almost double the material needed to build nuclear power plants. This is due to the massive size of coal plant boilers and pollution control equipment. Conversely, natural gas combined cycle plants take 3.3 metric tons of steel and 27 cubic meters of concrete—explaining why natural gas is such an attractive fuel, <u>if</u> it is cheap.

But what about new nuclear construction? Here are some of the results of our U.C. Berkeley study.

[SLIDE 5]

The nuclear power plants that we built in the 1970's were very efficient in their use of steel and concrete. In response to the Three Mile Island accident, however, "bloat" occurred in the designs of new, evolutionary reactors, with steel and concrete inputs increasing by 25 to 50 percent. This is the case for the ABWR, first built in Japan in the 1990's, and for the EPR, the new European plant design which be built in Finland.

But a major change has occurred with the new nuclear plant designs that will be built in the United States. These new designs—the ESBWR and the AP-1000—use passive safety systems, that replace the external cooling supplies, large pumps, and diesel generators used for emergency cooling in the old plant designs with simple, gravity driven heat exchangers.

These changes result in large reductions in steel and concrete inputs for these new passive plant designs—actually below the values of our 1970's plants. Thus we can expect, if they are built in the time periods demonstrated in Japan, that these new nuclear plants can have the lowest construction costs of any reactors every built.

Another point needs emphasis. In these new passive plant designs, the safety equipment does not require routine surveillance and maintenance, and therefore is placed in highly inaccessible locations. This inaccessibility will greatly reduce the difficulty of protecting this equipment from terrorist attack. Likewise, these plants all have below-grade spent fuel pools. These features will greatly reduce the size and cost of the security forces required to protect these plants, compared to our current nuclear plants.

Following cost and security, now let's consider nuclear waste management.

[SLIDE 6]

In 2002, the United States selected Yucca Mountain, in southern Nevada, as the site for a geologic repository for high-level waste and spent fuel. At Yucca Mountain the primary safety consideration involves the potential that, perhaps 70,000 to a few hundred thousand years from now when disposal canisters corrode, some radioactive material may be released into groundwater that flows into the Armagosa Valley.

For perspective, this slide shows the groundwater that humans have already contaminated with nitrate and perchlorate here in California, and groundwater that nature has already contaminated with arsenic. The tiny red box, on the right, shows the scale of the impact that Yucca Mountain might have. In the expanded figure, we can see that a modest fraction of the groundwater available in the Armagosa Valley might become unusable, still leaving large amounts available for consumption.

As of last Monday when the EPA issued a revised draft safety standard, Yucca Mountain also became the first place, in the entire history of the United States, where we will, for the first time, require that human health and safety be protected out to one-million years. This new requirement is unprecedented—current mining and coal wastes are exempted from the definition of hazardous wastes by statute, toxic heavy metals disposal compliance times are of order of only a hundred years, even though we know that the hazards from these wastes will persist for far longer periods. The longest compliance times required for any wastes are 10,000 years for deep-borehole disposal of chemicals, and 10,000 years for the current WIPP nuclear waste repository in New Mexico. Yucca Mountain will therefore set a new precedent for long-term protection that we should aspire to meet for all hazardous waste disposal.

California law prohibits new nuclear plant construction until the Energy Commission finds that there exists a demonstrated technology for the disposal of spent fuel and nuclear waste. There are two events that might trigger this finding. One could be the issuance of a construction permit for Yucca Mountain by the Nuclear Regulatory Commission, something we expect may happen before 2010.

However, under the U.S. Nuclear Waste Policy Act (NWPA), Yucca Mountain has a statutory limit of 63,000 metric tons of commercial spent fuel. This is nothing to sneeze at, since this quantity of spent fuel is equivalent to the mining and combustion of 5-billion tons of coal to produce equivalent electricity. But our current plants will hit this limit some time between 2010 and 2014.

Conversely, the Energy Commission may decide to lift the construction moratorium at the time that the Nuclear Waste Policy Act is amended to define the disposition path for spent fuel past the current statutory limit. Here, it is important to recognize that the Yucca Mountain site has the physical capacity to hold all of the spent fuel from our current reactors, plus spent fuel from a significant number of new reactors, perhaps 25 to 50 gigawatts or more. Also important is the fact that all recent analyses have shown that advanced fuel cycle technologies can increase this capacity by a factor of 50 to 100. This would permit waste management for many centuries of U.S. nuclear energy production, with a single repository site.

At U.C. Berkeley, we are currently working to develop a tradable repository space permit system that could be applied to Yucca Mountain, in collaboration with colleagues at the U.C.-managed Lawrence Livermore National Laboratory. Under a tradable repository space permit system, all nuclear materials would have a guaranteed disposal pathway, so that local communities will never again need to worry that interim storage could become *de facto* permanent storage.

At the same time, a space permit system would create an economic incentive for utilities to gradually deploy advanced fuels and fuel cycle technologies that would reduce and then reverse the rate of spent fuel accumulation. In fact, we expect that a permit system would eliminate almost completely the incentive to ship any materials to Yucca Mountain for at least several decades, except for defense wastes and limited quantities of spent fuel from decommissioned reactor sites like Rancho Seco and Humbolt Bay in California. We will, of course, be very happy to share the results of this ongoing work with the Energy Commission.

[SLIDE 7]

In my brief remaining time, let me mention a few points on the issues of the nuclear workforce and nuclear engineering education.

The nuclear energy sector clearly faces important workforce challenges, due to the combination of substantial growth and significant retirements that will occur during this next decade. However, the industry is intensely aware of these challenges. Evidence for this can be found in the current substantial recruiting efforts by utilities, including PG&E and Southern California Edison, in workforce committees formed by both the Nuclear Energy Institute and the American Nuclear Society, and in the substantial fraction, $24 million per year, of current U.S. Department of Energy nuclear energy funding aimed directly at universities to support nuclear engineering research and education.

Student interest in nuclear engineering began its rebound in 1997. For some reason, the strongest growth has been in Texas…but interestingly, this growth started well before 2001 and before the new National Energy Policy was issued. Instead, the turn around in current nuclear power plant performance gets the major credit. Let me say that today our engineering students, across all of the engineering disciplines, are extraordinarily bright and capable, and with current computers they now have tools to model and design new systems as never before. Engineering students today are impressive for another reason—they are actively interested in issues of ethics and the environment, and they are willing to question conventional wisdom.

[SLIDE 8]

To conclude, we will face major environmental challenges during the coming century, particularly in reducing carbon dioxide emissions from our use of fossil fuels. Many people do not realize that by deploying nuclear power at large scale, France was able to close its last coal mine in April, 2004. The same potential exists in the United States. Thus we commend the Energy Commission for its review of nuclear energy technology, and the Department of Nuclear Engineering at U.C. Berkeley looks forward to supporting our state in its further efforts to examine, and potentially develop, this technology.